



US006636442B2

(12) **United States Patent**  
**Rowlandson et al.**

(10) **Patent No.:** **US 6,636,442 B2**  
(45) **Date of Patent:** **Oct. 21, 2003**

(54) **NON-VOLATILE MEMORY ELEMENT HAVING A CASCODED TRANSISTOR SCHEME TO REDUCE OXIDE FIELD STRESS**

(75) Inventors: **Michael Rowlandson**, Portland, OR (US); **Andrew Horch**, Sunnyvale, CA (US)

(73) Assignee: **Lattice Semiconductor Corporation**, Hillsboro, CA (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/059,624**

(22) Filed: **Jan. 29, 2002**

(65) **Prior Publication Data**

US 2003/0142549 A1 Jul. 31, 2003

(51) **Int. Cl.<sup>7</sup>** ..... **G11C 16/04**

(52) **U.S. Cl.** ..... **365/185.28; 365/185.05; 365/185.02**

(58) **Field of Search** ..... **365/185.28, 185.05, 365/185.02**

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,706,240 A \* 1/1998 Flocchi et al. .... 327/540  
5,914,514 A 6/1999 Dejenfelt ..... 257/322

\* cited by examiner

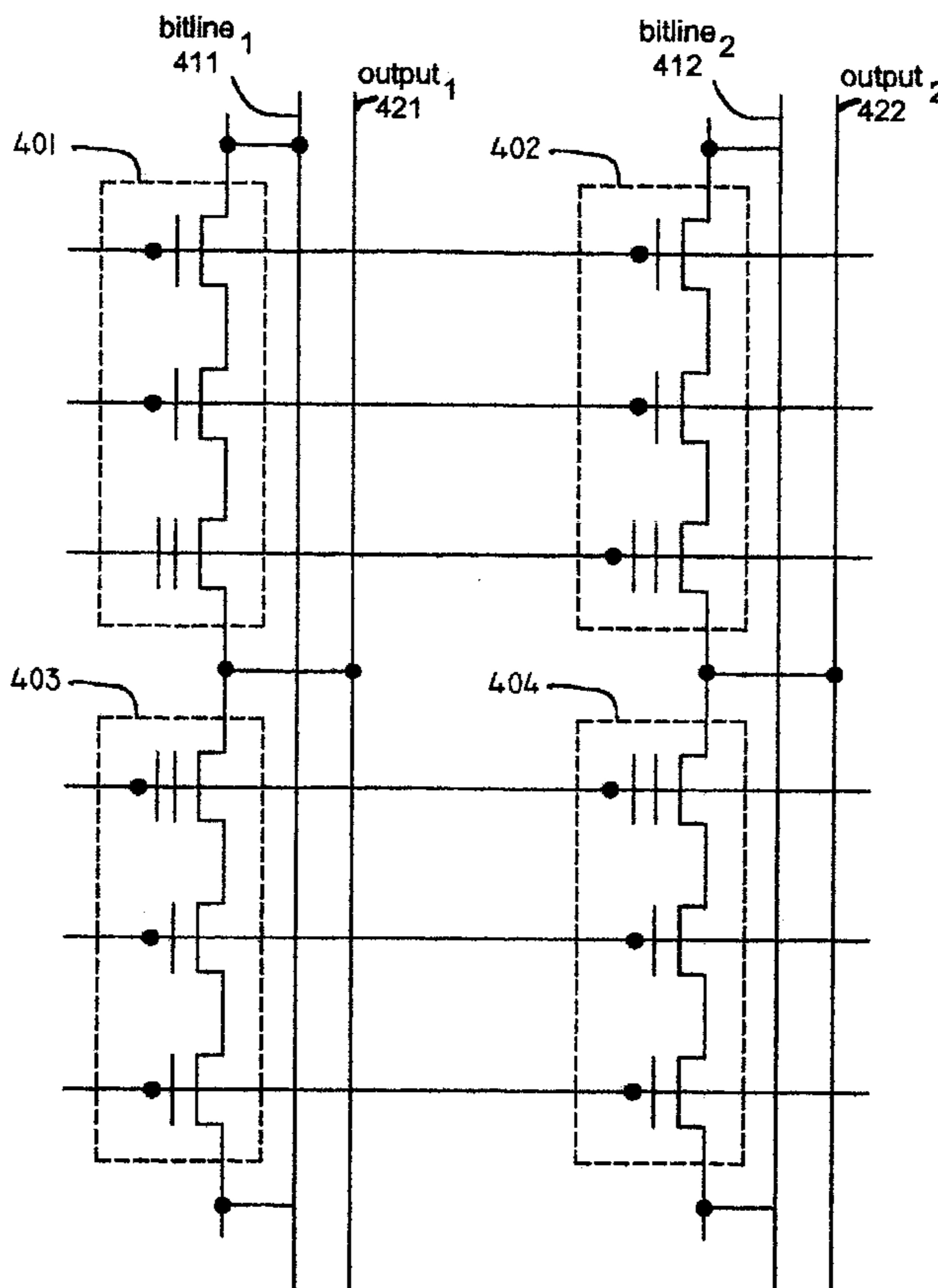
*Primary Examiner*—Huan Hoang

(74) *Attorney, Agent, or Firm*—Fliesler, Dubb, Meyer & Lovejoy, LLP

(57) **ABSTRACT**

A non-volatile memory cell (FIG. 3) is provided which includes three transistors, a floating gate non-volatile storage transistor (303) and two cascode connected select transistors (301–302). The two cascoded select transistors (301–302) act together to block the programming voltage when the memory cell is included in an array, and the memory cell is not selected for programming. A value of an unselect voltage applied to the gate of the first cascode connected transistor (301) is set to prevent breakdown of the oxide in the first cascode transistor (301) as well as the second cascode transistor (302). A value of an unselect voltage applied to the gate of the second cascode connected transistor (302) can be selected so that the voltage passed to the floating gate storage transistor (303) will not result in a program drain disturb, or source disturb condition.

**12 Claims, 2 Drawing Sheets**



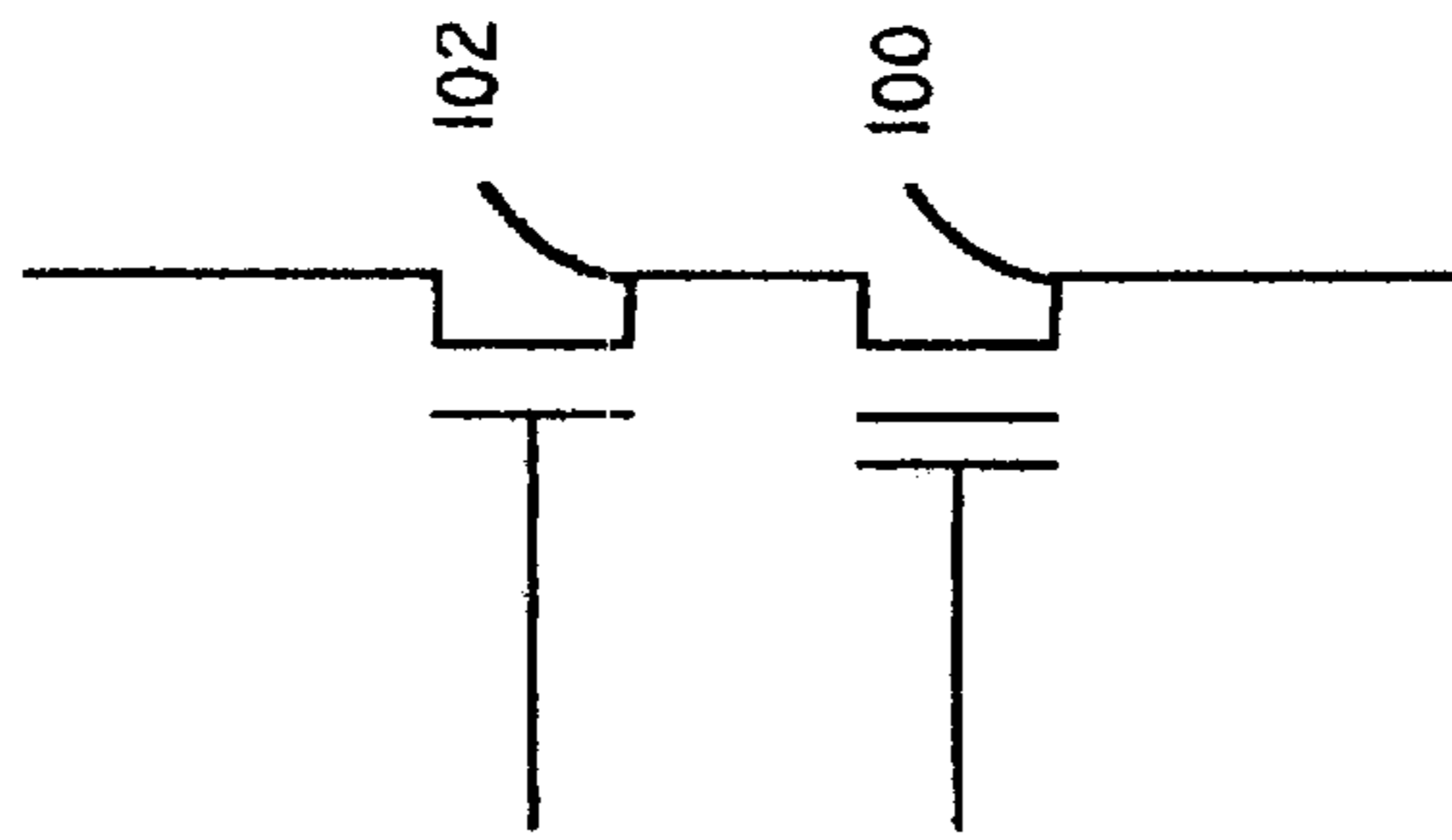


FIG. 1  
PRIOR ART

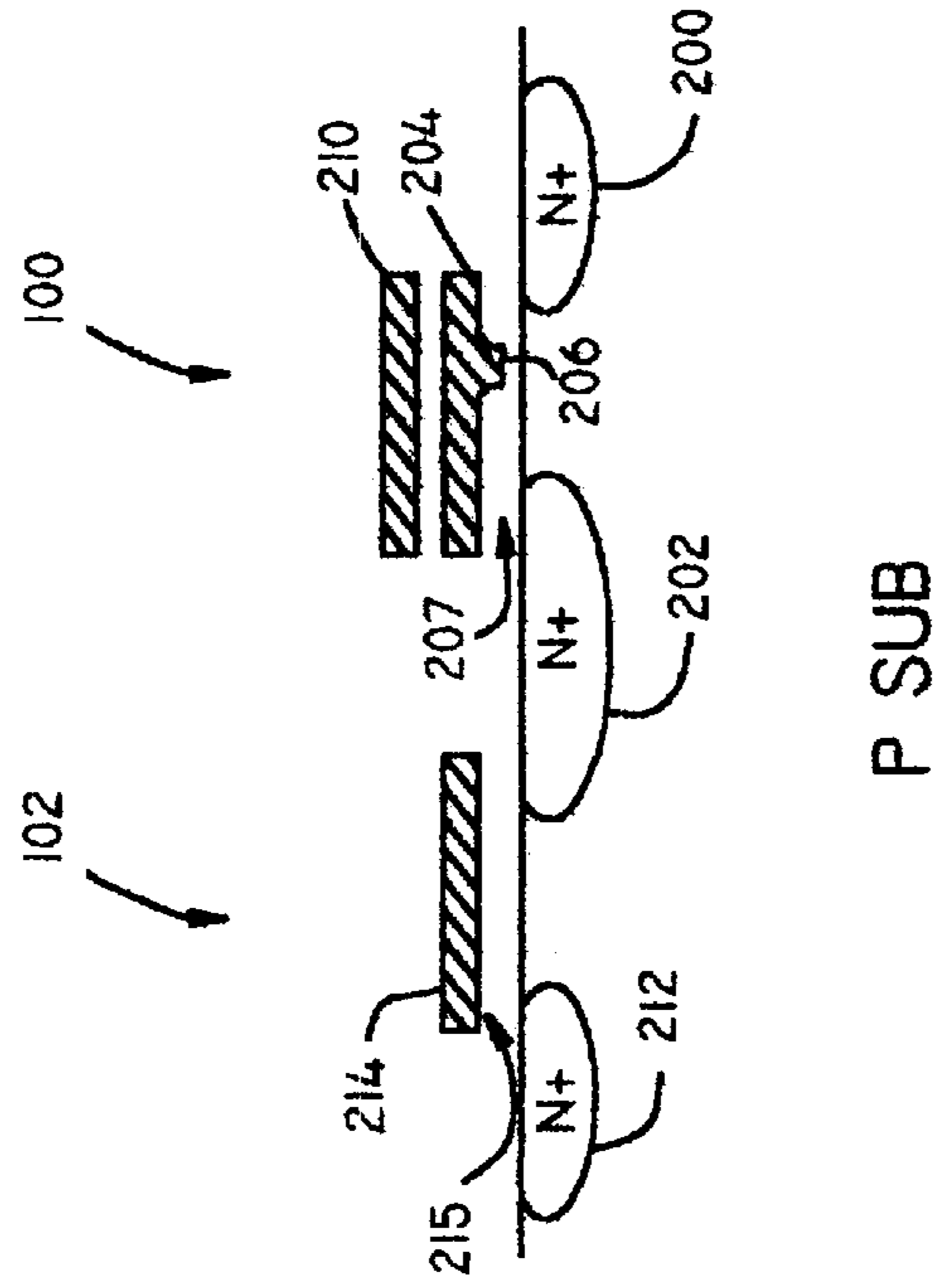


FIG. 2  
PRIOR ART

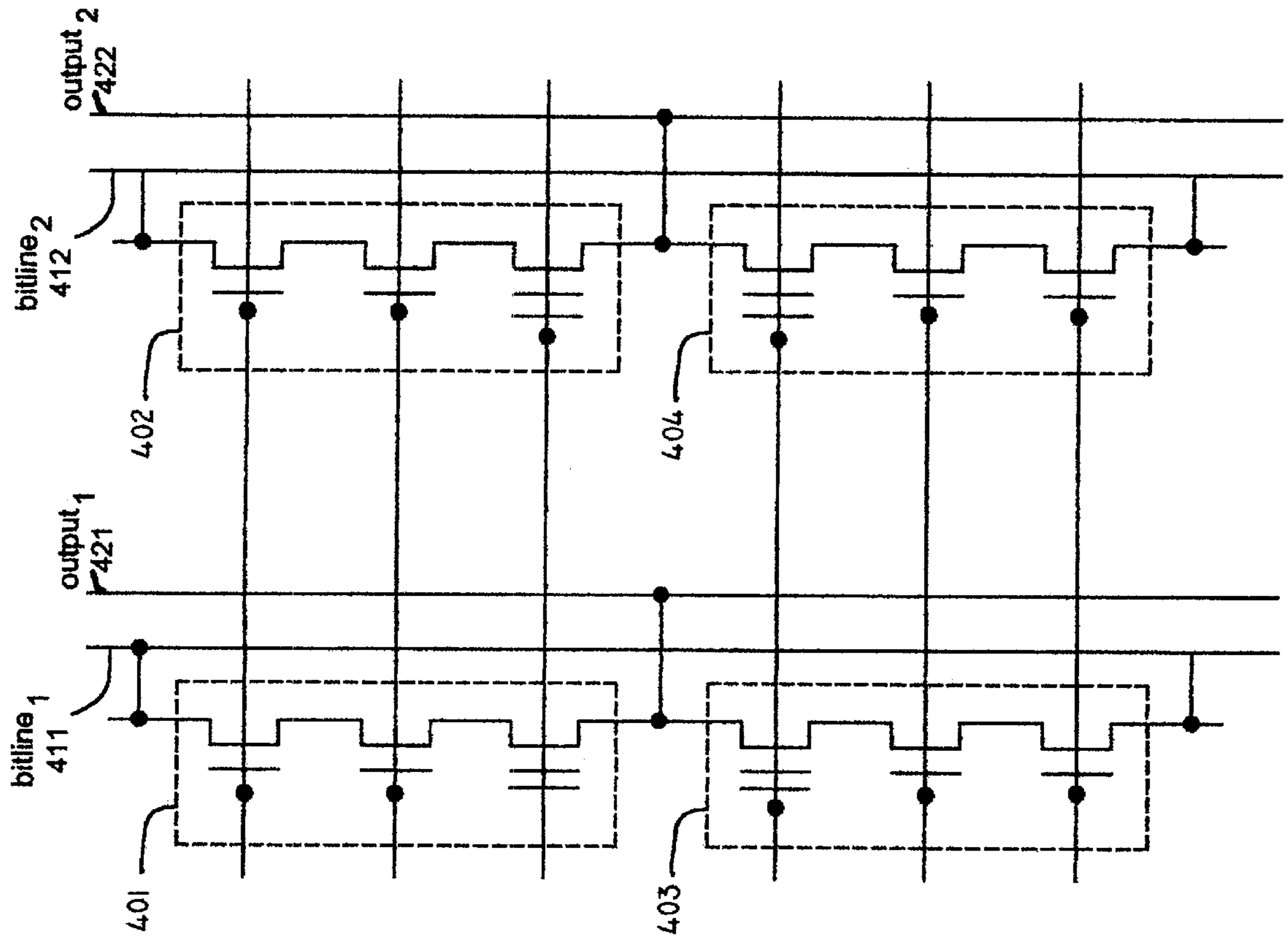


FIG. 4

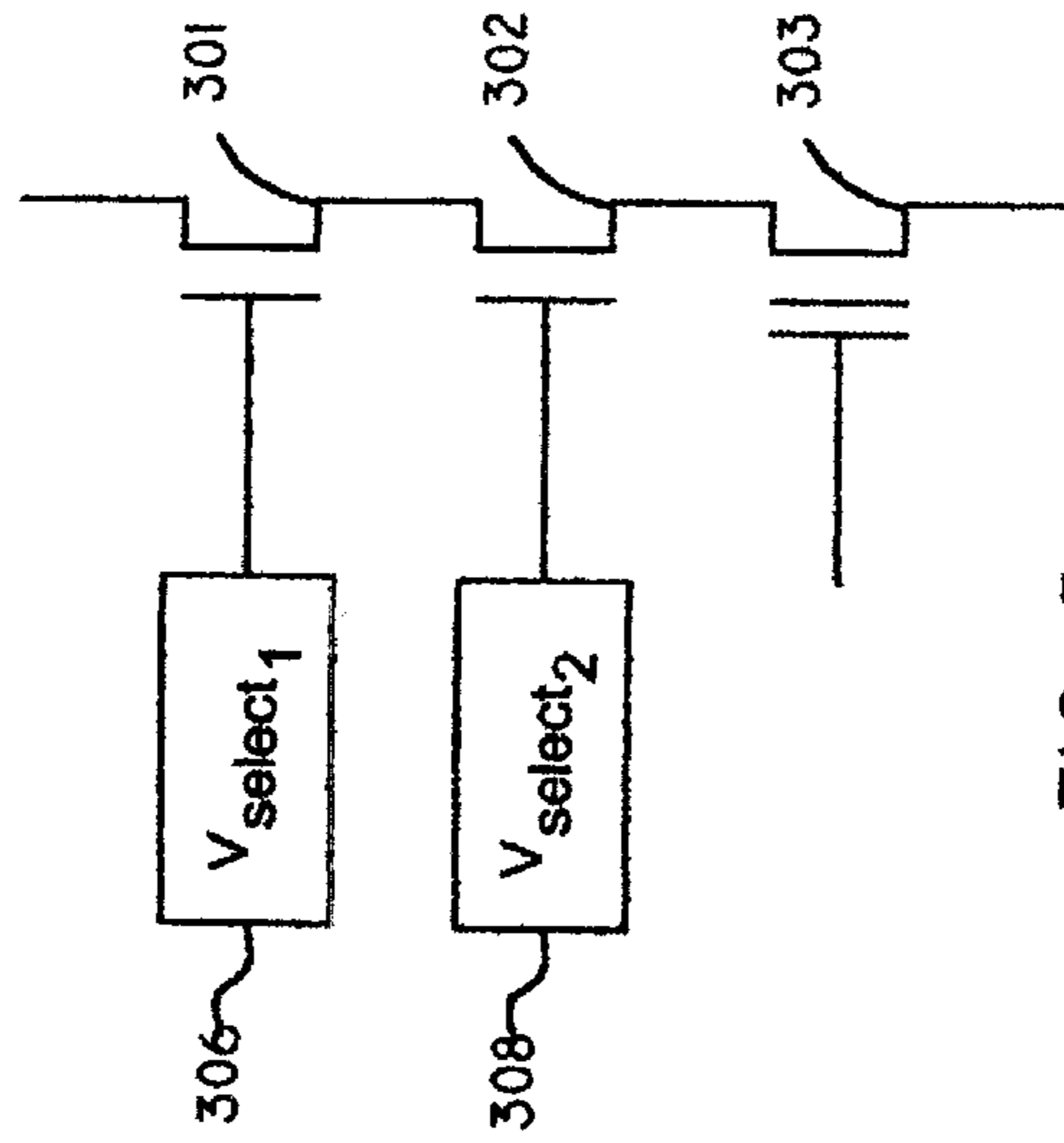


FIG. 3

**NON-VOLATILE MEMORY ELEMENT  
HAVING A CASCODED TRANSISTOR  
SCHEME TO REDUCE OXIDE FIELD  
STRESS**

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to non-volatile memory cells with both a select transistor and a floating gate storage transistor used with high density programmable logic devices (PLDs). More particularly, the present invention relates to a method for reducing field oxide stress and program disturb conditions in the memory cell.

2. Background

FIG. 1 shows a conventional two transistor non-volatile memory cell used with a PLD. The memory cell includes a nonvolatile floating gate storage transistor **100**, along with a conventional select memory transistor **102**. The select transistor **102** is used to prevent programming of the floating gate storage transistor **100** when the two transistor cell is in an array of memory cells and other cells on the same bitline are being programmed.

FIG. 2 shows a cross-section of the layout for the conventional two transistor memory cell of FIG. 1. As shown, the floating gate storage transistor **100** is an NMOS device including an n+ type source region **200** and an n+ type drain region **202** provided in a p type substrate. The floating gate is a polysilicon region **204** with a portion **206** which creates a tunneling region in the oxide material **207** between the polysilicon gate **204** and the p type substrate. The floating gate **204** is provided over the channel in the substrate between the source **200** and drain **202**. A control gate **210** is provided above the polysilicon gate **206**, and is formed from a conductive material to which gate control signals are applied.

The select transistor **102** has a source **202** formed in common with the drain of the storage transistor **100**. An n+ type drain region **212** of the select transistor **102** is formed in the p substrate with a conductive gate region **214** overlying the channel between the source **202** and drain **212**. An oxide material **215** is provided between the gate **214** and channel of transistor **102**.

The select transistor **102** is used to prevent a program disturb condition. The program disturb condition can be a drain disturb event which occurs in a floating gate transistor in an unselected memory cell connected to the same bit line as a selected memory cell transistor. The high bit line program voltage and low unselect gate voltage applied to a floating gate storage transistor to prevent programming when a select transistor is not used causes a high electric field to be applied between the gate and drain of the floating gate transistor. The high electric field may cause electrons to tunnel between the floating gate and drain resulting in a drain disturb programming condition where the unselected cell is unintentionally programmed. Similarly, since the source electrode of the selected and unselected memory cells may be connected together on a bit line, a source disturb event can likewise cause an unintentional programming of unselected memory cells. A select transistor effectively blocks the bitline drain voltage from the storage transistor to prevent drain disturb or source disturb conditions.

With a high bit line programming voltage ( $V_{pp}$ ) now applied to the drain of a select transistor **102**, avalanche breakdown can occur in the select transistor causing dam-

age. With the high programming voltage applied to the bit line, and zero volts applied to the gate of the select transistor **102**, avalanche breakdown can occur through the oxide region **215** between the drain **212** and gate **214** resulting in damage to the oxide region **215**.

Instead of zero volts, an intermediate voltage ( $V_{unselect}$ ) can be applied to the gate of select transistors in memory cells which are not to be programmed. The value of  $V_{unselect}$  is bounded by a "voltage box" on the high side by a soft programming condition, where insufficient voltage should be passed through to the programming element to allow any programming due to a disturb condition. The value of  $V_{unselect}$  is bounded on the low side by the oxide breakdown concerns where the voltage from the drain of the select device to the gate of the select device exceeds the intrinsic breakdown voltage of the insulating oxide film.

SUMMARY

In accordance with the present invention, a voltage box on select transistors of conventional memory cells is avoided.

In accordance with the present invention, a memory cell is provided including three transistors, a floating gate non-volatile storage transistor and two cascode connected select transistors. The two cascoded select transistors act together to block the bit line programming voltage when the memory cell is connected in an array, and the cell is not selected for programming. A value of an unselect voltage ( $V_{unselect1}$ ) applied to the gate of the first cascode connected transistor connected directly to the bit line can be set to eliminate the select transistor oxide breakdown concern. A value of an unselect voltage ( $V_{unselect2}$ ) applied to the gate of the second transistor can be selected so that the voltage passed to the floating gate storage transistor will not result in a program disturb condition.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described with respect to particular embodiments thereof, and references will be made to the drawings in which:

FIG. 1 shows a conventional two transistor memory cell;

FIG. 2 shows a cross section of a layout for the memory cell of FIG. 1;

FIG. 3 shows a memory cell in accordance with the present invention; and

FIG. 4 shows a group of memory cells as shown in FIG. 3 connected in an array configuration.

DETAILED DESCRIPTION

FIG. 3 shows a memory cell in accordance with the present invention. The memory cell includes two cascode connected select transistors **301** and **302** and a floating gate storage transistor **303**. The transistors **301-303** have source-drain paths connected in series, and select/unselect voltages applied from a first voltage reference labeled  $V_{select1}$  **306** and a second voltage reference labeled  $V_{select2}$  **308** to the respective gates of transistors **301** and **302**.

Transistors **301** and **302** are connected in a cascode configuration indicating that the transistors are turned on and off by varying voltage applied to the drain with the gate voltage fixed, rather than varying the gate voltage. In a cascode transistor with  $(v_g - v_d) > v_t$ , wherein  $v_g$  is the gate voltage,  $v_d$  is the drain voltage, and  $v_t$  is the threshold voltage of the transistor, the cascode transistor will turn on. With  $(v_g - v_d) < v_t$  the cascode transistor will turn off.

Each of the transistors **301-303** are NMOS devices. A layout of transistors **302** and **303** is similar to the layout of

conventional transistors **100** and **102** shown in FIG. 2. The layout of transistor **301** will be similar to the layout for transistor **302**, with transistor **301** having a source in common with the drain of transistor **302**.

The two cascoded select transistors **301–302** act together to block the programming voltage when programming of the cell is not desired, and to avoid the “voltage box” effect described previously. To avoid the voltage box effect, the value of  $V_{unselect1}$  applied from the voltage reference **306** to the gate of transistor **301** when the memory cell is not selected for programming is set exclusively by the oxide breakdown concern. The value  $V_{unselect1}$  will be set to cause a drain to gate voltage drop in transistor **301**, so that the voltage on the source of transistor **302** is significantly lower than if one select transistor were used, but high enough to avoid avalanche breakdown and possible oxide damage in transistor **301**. The voltage passed to the drain of transistor **302** will be some fraction of  $V_{pp}$  applied to the bitline during programming as controlled by  $V_{unselect1}$ .

The scheme of using two select cascode transistors to avoiding oxide damage can be extended to any number of select cascode transistors connected in a series configuration. The values of the unselect voltages applied to the gates of the multiple transistors will be chosen to cause a slight voltage drop across each select transistor without damaging the transistor, so that the bit line programming voltage will not damage any one transistor in the series. If the cell is selected for programming, a value of  $V_{pp}$  or higher can be applied to the gate of each of the select transistors to assure the programming voltage  $V_{pp}$  is applied to the gate of the floating gate storage transistor **303**.

The voltage  $V_{unselect2}$  applied from the voltage reference **308** to the gate of transistor **302** is selected so that the voltage passed, to the floating gate storage transistor **303** will not result in a program disturb condition. A program disturb condition can occur at a voltage less than  $\frac{1}{2}$  of  $V_{pp}$ . The select voltage  $V_{unselect2}$  will cause a drain to gate voltage drop through transistor **302**, so that a voltage less than the drain disturb voltage is applied to the drain of transistor **303**.

FIG. 4 shows four memory cells **401–404**, as shown in FIG. 3 connected in an array configuration. The memory cells **401** and **403** are connected so that the source of the floating gate storage transistor from each memory cell is connected to a common output line **421**. Since the output from both cells **401** and **403** are connected to the common output line, only one cell can be selected at a time. Alternatively, the cells **401** and **403** can be connected to separate outputs at the source of their floating gate storage transistors.

The memory cells **401** and **403** are further connected to a common bitline **411** at the drain of their first cascode select transistor. Memory cells **402** and **404** are similarly connected to a common output **422**, and a common bitline **412**, separate from the memory cells **401** and **403**. The memory cells **401** and **402** share common gate or wordline select voltage inputs. Similarly, memory cells **403** and **404** share common wordline select voltage inputs.

Although the present invention has been described above with particularity, this was merely to teach one of ordinary skill in the art how to make and use the invention. Many other modifications will fall within the scope of the invention, as that scope is defined by the claims provided below.

What is claimed is:

1. A method for preventing programming of a given non-volatile memory cell in an array of memory cells, the

given memory cell including a floating gate transistor having a source-drain path connected to the source-drain path of a second of two select transistors which have source-drain paths connected in series, wherein a programming voltage is applied to a bitline connected to the source-drain path of a first of the two select transistors, the method comprising the steps of:

applying a first select voltage to the gate of the first select transistor, the first select voltage having a value set to prevent damage to an oxide material between the gate and drain of the first select transistor; and

applying a second select voltage to the gate of the second select transistor, the second select voltage having a value set to prevent the charge stored by the floating gate transistor from being disturbed.

2. A memory cell comprising:

a first select transistor having a source-drain path and a gate;

a second select transistor having a source-drain path connected in series with the source-drain path of the first select transistor, and having a gate;

a floating gate storage transistor having a source-drain path connected in series with the source-drain path of the second select transistor;

a means for applying a voltage to the gate of the first select transistor so that when a bitline programming voltage is applied to the source-drain path of the first select transistor to enable programming of the floating gate storage transistor, and when programming of the floating gate storage transistor is not desired, damage will not occur to an oxide material between the gate and drain of the first select transistor; and

a means for applying a voltage to the gate of the second select transistor so that when the bitline programming voltage is applied to the source-drain path of the first select transistor, and programming of the floating gate storage transistor is not desired, charge stored by the floating gate storage transistor will not be disturbed.

3. A memory cell comprising:

a first select transistor having a source-drain path and a gate;

a second select transistor having a source-drain path connected in series with the source-drain path of the first select transistor, and having a gate;

a floating gate storage transistor having a source-drain path connected in series with the source-drain path of the second select transistor;

a first voltage reference configured for providing a voltage to the gate of the first select transistor so that when a bitline programming voltage is applied to the source-drain path of the first select transistor to enable programming of the floating gate storage transistor, and when programming of the floating gate storage transistor is not desired, damage will not occur to an oxide material between the gate and drain of the first select transistor; and

a second voltage reference configured for providing a voltage to the gate of the second select transistor so that when the bitline programming voltage is applied to the source-drain path of the first select transistor, and programming of the floating gate storage transistor is not desired, charge stored by the floating gate storage transistor will not be disturbed.

4. The memory cell of claim 3, wherein the first select transistor, the second select transistor and the floating gate storage transistor comprise NMOS devices.

5

5. The memory cell of claim 3, wherein the first select transistor and the second select transistor comprise volatile devices.

6. An array of memory cell transistors comprising: memory cells comprising:

- a first select transistor having a source-drain path and a gate;
- a second select transistor having a source-drain path connected in series with the source-drain path of the first select transistor, and having a gate;
- a floating gate storage transistor having a source-drain path connected in series with the source-drain path of the second select transistor;
- a first array output connected to the source-drain path of the floating gate storage transistor in a first portion of the memory cells; and
- a second array output connected to the source-drain path of the floating gate storage transistor in a second portion of the memory cells.

7. The array of claim 6, further comprising:

- a first bitline connected to the source-drain path of the first select transistor in the first portion of the memory cells; and
- a second bitline connected to the source-drain path of the first select transistor in the second portion of the memory cells.

8. The memory cell of claim 7, further comprising:

- a first voltage reference configured for providing a voltage to the gate of the first select transistor in a third portion of the memory cells, the third portion including some memory cells from the first portion and the second portion of memory cells, so that when a bitline programming voltage is applied to the source-drain path of the first select transistor in the third portion of memory cells to enable programming of the floating gate storage transistor in the third portion of memory cells, and when programming of the floating gate storage transistor in the third portion of memory cells is not desired, damage will not occur to an oxide material

6

between the gate and drain of the first select transistor in the third portion of memory cells; and

- a second voltage reference configured for providing a voltage to the gate of the second select transistor in the third portion of the memory cells so that when the bitline programming voltage is applied to the source-drain path of the first select transistor in at least some of the third portion of memory cells, and programming of the floating gate storage transistor in the third portion of memory cells is not desired, charge stored by the floating gate storage transistor in the third portion of memory cells will not be disturbed.

9. The memory cell of claim 8, wherein the first select transistor, the second select transistor and the floating gate storage transistor of the memory cells comprise NMOS devices.

10. The memory cell of claim 9, wherein the first select transistor and the second select transistor of the memory cells comprise volatile devices.

11. A memory cell comprising:

- a first select transistor having a source-drain path and a gate;
- a second select transistor having a source-drain path in series with the source-drain path of the first select transistor, and having a gate;
- a floating gate transistor having a source-drain path connected in series with the source-drain path of the second select transistor;
- an output line connected to the source-drain path of the floating gate transistor; and
- a bitline connected to the source-drain path of the first select transistor.

12. The array of memory cells of claim 11, wherein the memory cells share a common output line connected to the source drain path of the floating gate transistor of each cell and share a common bitline connected to the source-drain path of the first select transistor of each cell.

\* \* \* \* \*